

NIAGARA'S POWER

PAST, PRESENT,
PROSPECTIVE

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A D D R E S S

TO THE MEMBERS OF THE EMPIRE
CLUB, 19th JANUARY, 1905, GIVEN
BY MR. FREDERIC NICHOLLS.

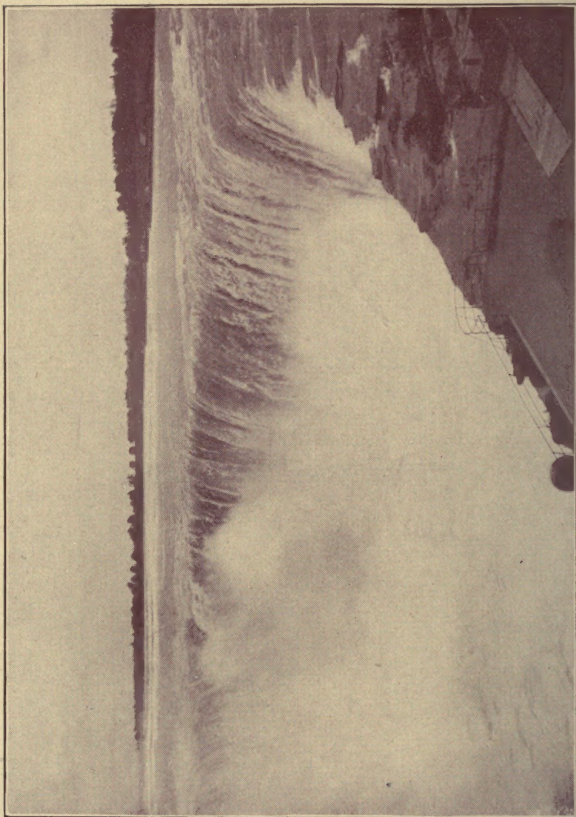
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HORSE SHOE FALLS.

NIAGARA'S POWER PAST, PRESENT, PROSPECTIVE



WHEN, at the invitation of your President, Colonel Mason, I consented to prepare a short paper, dealing with the development of electrical power at Niagara Falls, I had little idea of the difficulty of the task. With so much material at hand, I knew I could easily fill in the allotted time of thirty minutes, but my troubles arose from the wealth of material with which I was confronted. When I commenced to jot down the various matters about which I thought my audience would like to hear, I found that instead of one-half hour, it would take very much longer to even touch upon the various matters of interest connected with the title of the paper. Condensation is much more difficult than elaboration, and I have necessarily to omit much, but trust that which I have chosen to place before you may awaken sufficient interest to induce you all to again visit Niagara

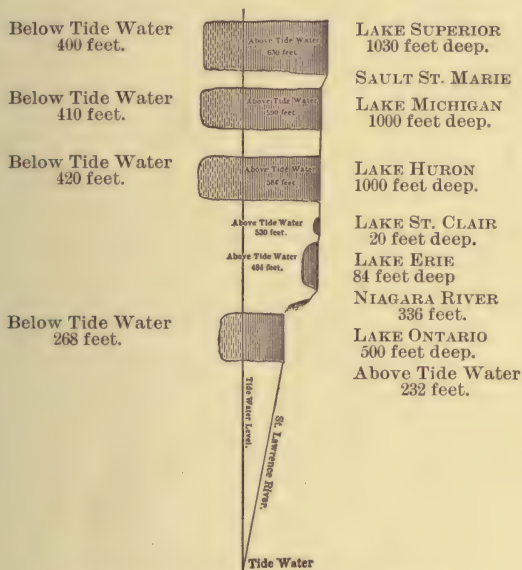
Falls, and witness the stupendous engineering problems that have been already overcome, and those which are in process of being solved.

Many writers and poets have enriched our literature with romantic tales and thrilling narratives of the Niagara region, but time forbids me to dwell upon these, and, besides, I have undertaken to deal only with more prosaic matters. Should you desire to refresh your memories regarding the occupation of this historic district by the North American Indian, its discovery by Jesuit Fathers, its alternate conquest by France and England, each in turn aided and beset by various Indian tribes, such authors as Parkman, Fenimore Cooper, and others will treat you to fact or fancy to suit your inclinations.

Much, however, has been written by scientists in reference to the early geological history of Niagara Falls. Mr. J. W. Spencer, F.G.S., in a paper read before a meeting of the American Association for the Advancement of Science, in 1894, refers to many historical facts.

Although the computed age of the Niagara River is 32,000 years, it was not until about 8000 years ago that the waters of the Huron Basin were discharged by the way of Niagara,

their course having previously been along the Ottawa Valley, but owing to many geological upheavals and deformations, the water-shed of the Great Lakes has changed from time to time. Mr. Spencer, who has made a life-long study of this subject, concludes that at the present rate



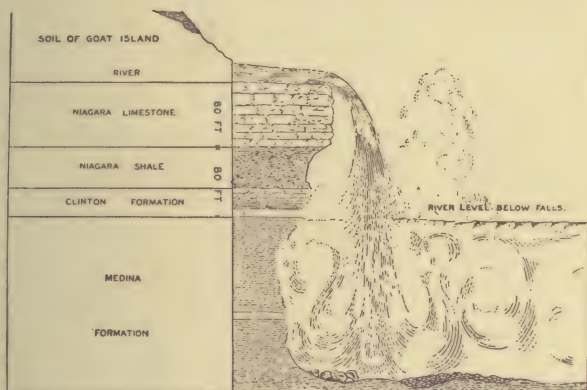
DEPTHS OF WATER IN GREAT LAKES.

of terrestrial uplift of the rocky floor of the Niagara at the outlet of Lake Erie, the drainage of the Great Lakes will be diverted into the Mississippi, by way of Chicago, within the next five or six thousand years. An elevation of 60

feet at the outlet of Lake Erie, would bring the rocky floor of the channel as high as the bed of the river at the Chicago divide, and an elevation of 70 feet would divert the drainage, and history would repeat itself by again diverting the overflow of the Great Lakes into a new channel, with this difference, that, while the Ottawa Valley outlet of ancient times was entirely within what is now Canadian territory, and the present outlet is in international territory, with about 80 per cent. of the available water flowing over the Canadian Falls, the Mississippi outlet will be entirely within the boundaries of the present United States, but, as we are promised not less than 5000 years within which to take advantage of conditions as we now find them, we can safely leave posterity to take care of this phase of the question.

A more imminent danger, perhaps, than the terrestrial uplift is the rate of recession of the Canadian Falls. Before the survey of 1842, the only data for estimating the rate of recession at the Niagara Gorge were observations of the people of the neighborhood, and it has been variously estimated to have been from one foot to three feet per year. Modern investigators, basing their calculations on the surveys of 1842,

1875 and 1883, estimate the recession of the Canadian Fall at from three to five feet per year. The principal cause of this recession is from the fact that the cliff between the upper and lower rivers is not composed of solid rock, but is divided into five strata, which dip towards the south at the rate of about 25 feet to the mile. The upper stratum consists of compact



PROF SHALER'S SECTIONAL VIEW OF NIAGARA.

Niagara limestone, about 80 feet in thickness. Underneath is comparatively soft Niagara shale, of about the same thickness. Numbers 3 and 5 are also strata of hard rock with a softer rock intervening, so that the manner of recession is very easily understood. The softer rocks more rapidly wear away, thus undermining the harder

rocks above, leaving them to project over and finally to break off in huge fragments. The continuity of the under-lying soft strata insures the continuance of a projecting stratum at the top and a perpendicular plunge of the water when passing over it.

If we compute the possible recession at the maximum estimated rate of five feet per year, it will take several hundred years before the various power developments can be injuriously affected, and several thousand years before the outlet from Lake Erie will be reached.

In 1896, my good friend, Mr. Thomas Commerford Martin, editor of *The Electrical World and Engineer*, read a paper before the Royal Institution of Great Britain, entitled, "Utilization of Niagara," and I quote some of my facts from his carefully prepared statistics.

He states that at Niagara there is discharged, through two narrowing precipitous channels, only 3,800 feet wide and 160 feet high, the contents of 6000 cubic miles of water, with a reservoir area of 90,000 square miles, draining 300,000 square miles of territory. The ordinary overspill of this Atlantic set on edge has been determined to be equal to about 275,000 cubic feet per second, and the quantity passing is

estimated as high as one million tons of water per hour. The drifting of a ship over the Horse Shoe Falls has proved it to have a thickness at the centre of the crescent of over 16 feet.

Between Lake Erie and Lake Ontario there is a total difference of level of 300 feet, and the amount of power represented by the water of the river has been estimated on different bases



FIRST KNOWN VIEW OF NIAGARA FALLS, 1697.

from 6,750,000 up to not less than 16,800,000 horse power, the latter being a rough calculation of Sir Wm. Siemens, who, in 1877, was the first to suggest the use of electricity as the modern and feasible agent of converting into useful power some of this majestic, but squandered energy.

Having thus briefly referred to the early geological history of the River and Falls, coupled with such explanatory statistics as will enable my audience to better follow the description of the power developments which are referred to later, I will commence at once to deal with the material interests of modern times, although it is with regret that in so doing I have to delete much interesting matter dealing with other episodes of the Niagara River and district.

You are all familiar with the efforts of the late Lord Dufferin, when Governor General of Canada, to secure for a public park the lands immediately adjacent to the Horse Shoe Falls and Upper Rapids. As a direct result of Lord Dufferin's efforts, an Act was passed by the Ontario Legislature on the 5th of March, 1880, the preamble of which reads as follows:

"Whereas, it has been proposed that the Government of the Dominion of Canada and the State of New York, should take steps to restore to some extent the scenery around the Falls of Niagara to its natural condition, and to preserve same from further deterioration, and also to afford to travellers and others facilities for observing the points of interest in the vicinity; and whereas it is desirable, that any action the Government or Parliament of Canada may desire to take for the

purpose of acquiring lands in the neighborhood, with a view of the said object, should be handled in manner hereinafter appearing as relates to any matter within the authority of the Legislature of Ontario, by and with the advice and consent of the Legislative Assembly of the Province of Ontario, enacts as follows:"

As will be noted, this Act of the Province of Ontario, passed in 1880, was for the purpose of permitting the Dominion Government, with the consent of the Ontario Government, to acquire the lands necessary for park purposes, as Sir Oliver Mowat, the then Premier of Ontario, who most heartily favored the park projects, took the ground that the park should be a national one, and that it was the duty of the Dominion Government to take the necessary action for its foundation, but owing to the Dominion Government not having availed itself of the opportunity thus afforded, practically nothing was done during the next ensuing five years.

The Ontario Government then took the matter vigorously in hand, and during the Session of 1885 passed another Act, the preamble of which reads as follows:

"Whereas, the Government of the Dominion of Canada has not availed itself of the provisions of the Act passed in the

forty-third year of Her Majesty's reign, entitled, "An Act Respecting Niagara Falls and the Adjacent Territory," and as it is desirable that other means should be taken to restore, to some extent, the scenery around the Falls of Niagara to its natural condition, and to preserve the same from further deterioration, and to afford travellers and others facilities for observing the points of interest in the vicinity; therefore, Her Majesty by and with the advice and consent of the Legislature of the Province of Ontario, enacts as follows:"

This Act, in addition to enacting methods whereby the lands, privileges, etc., were to be acquired, provided for the appointment by the Government of three Honorary Commissioners, whose first duties were:

"To report as to the plans which, in their opinion, should be adopted for securing the permanent preservation of the properties, and as to the way in which the same should be managed, and in the establishment of same as a public park, with such other matters as the Commissioners may think fit."

The Commissioners first appointed were Sir Casimir Gzowski, J. W. Langmuir, and J. Grant Macdonald.

The Commissioners lost no time in making their first report, which is dated September 18th, 1885, or a few months only after the passing of the Act.

This report was followed closely by others, and, if time permitted, much of interest and value could be learned therefrom. Suffice it to say, that the Commissioners finally secured the various lands and privileges necessary, and on the 5th of March, 1887, they reported the completion of their labors in this regard, and advised the Government that \$525,000.00 would be required to pay the sum awarded by the arbitrators for the purchase of the lands and privileges.

During the Session of 1887 another Act was passed, increasing the number of the Board of Commissioners from 3 to 5, vesting the lands heretofore or hereafter to be acquired in the Commissioners, and giving authority for the acquiring of additional lands and privileges.

From this time until 1899 the Commissioners were engaged in the work of reconstruction, and in beautifying the Park by removing unsightly structures, and by constructing roads, walks, bridges, etc., which would afford facilities to the public to view all the points of interest, many of which had been more or less inaccessible.

No provision, however, had been made by the Government, when creating the Commission,



INTERNATIONAL RAILWAY AT TEMPEST POINT.

for the maintenance of the Park, other than by allowing certain moderate tolls to be charged for passengers crossing the Dufferin Island bridges, etc., and in the report of 1889 the following doleful paragraph appears :

“The Commissioners, after carefully considering the question are forced to admit that even with improved conditions the source from which the revenues are now drawn will prove inadequate to meet the annual cost of maintaining the park, exclusive of the payment of interest and sinking fund on the debentures.”

This brings me to that point in the history of the Canadian Falls where electricity first looms up as a factor in the situation.

The Commission had cast about for ways and means whereby they could increase their revenue. One scheme was the establishment of a line of coaches to run at stated times between the Mowat and Dufferin gates; another, more wisely adopted, was for the construction on the brink of the river of an electrical railway between the Park and Queenston, and the report goes on to say :

“The privileges of constructing a railway along the brink of the river, in the opinion of the Commissioners, should be a very valuable asset for the purpose of increasing the annual revenue of the Park.”

Having secured the consent of the Government to award the franchise for the construction and operation of an electric railway, an option to secure such a franchise was given to a syndicate of English capitalists, which was ultimately forfeited by their inability to raise the necessary funds.

An agreement was then entered into, on the 4th December, 1891, which authorized a Canadian Company, represented by Messrs. E. B. Osler, Wm. Hendrie, H. C. Hammond, and R. B. Angus, to construct and operate a railway, thereafter known as the Niagara Falls Park and River Railway Co., paying therefor an annual rental of \$10,000.00; and the income thus acquired not only assisted the Commissioners in making the revenue account more nearly equal to the expenditures, but was the first rental received from any electrical development at Niagara Falls.

I have pleasant memories of the construction of this line. The Canadian General Electric Company, which was then in its infancy, was awarded the contract for the manufacture of the electrical apparatus. This was our first large contract, as electrical contracts went in those days, and I remember standing by the 200 H.P.

generator at the time this line was publicly opened, proud to know that it was the largest generator which up to that time had been manufactured in Canada; and nothing will more clearly exemplify the march of progress in electrical science than to refer to the fact that, while in 1900 a 200 H.P. generator was the largest that had been built in this country, we are now building a number of 15,000 H.P. generators, which are the largest in the world, and which will generate power to be derived from this same Niagara River at the power house of the Electrical Development Company.

The next step towards electrical development at the Park was, when, during the same year, the Commissioners gave an option to another body of English capitalists of the sole right of using for power purposes the waters of the Niagara River within the Park, at an annual rental of \$25,000.00. This option was renewed by the Commissioners from time to time, upon the payment of an annual sum of \$25,000.00, so that from this time forward the Commissioners were in receipt of an income of \$10,000.00 from the Railway and \$25,000.00 from the proposed power company, making in all a total of \$35,000.00 per year on account of possibilities

of electrical development, as against \$4,000.00 per year from tolls, which had originally been expected to defray the cost of maintaining the Park. When all the concessions now granted are developed to their full capacity, the Commissioners will have an annual income of not less than \$250,000.00 per year.

Colonel Albert Shaw, who held the option for a monopoly of the power rights, being unable to interest the necessary English capital, associated with himself Mr. Wm. B. Rankine and others in the United States, and on the 4th of April, 1892, an Act of the Ontario Legislature was passed confirming the agreement made between the Commissioners and Col. Shaw, Wm. B. Rankine, and others, who had organized as the Canadian Niagara Power Company.

Mr. Rankine has since associated with himself some of the wealthiest and brainiest men in the United States, and is at present Vice-President of the Canadian Niagara Power Company, operating, however, under different conditions of franchise from those first granted, and his Company is the first of the three large power Companies on the Canadian side to commence active operations.

I have mentioned that the Canadian Niagara Power Co. is operating under a different franchise than that first secured under the Act of 1892, and I must briefly dwell on this subject, as were it not for the surrender of their monopoly clause there would be a different story to tell.

The first franchise was in all for a period of one hundred years, and the monopoly clause reads as follows:

“The Commissions shall not grant or confer upon any other Company or person any right to take or use the waters of the Niagara River within the limits of the Park, so long as this agreement is in force, nor will the Commissioners themselves engage in making use of the waters to generate electrical or pneumatic power except for the purposes of the Park, saving always in so far as regards the exceptions contained in paragraph 12 of this agreement (*i.e.*, the electrical railway franchise already granted).”

With this franchise went the obligation to have completed water connections for the development of 25,000 H.P., and have actually ready for use, supply and transmission 10,000 developed electrical H.P. by the first day of May, 1897, or over five years in which to construct.

Without further comment, I may say that the Canadian Niagara Power Company, for some sufficient reason no doubt, failed to develop

10,000 H.P. within the time allowed by their franchise, and a new era commenced when the Commissioners were again authorized to lease to others such additional power sites as were available after the final location by the Canadian Niagara Power Company of the limits of their concession.

In order to be as brief as possible in dealing with what I consider to be historic negotiations, I will skip from the year 1892, when the monopoly franchise was granted, until the year 1899. The Park Commissioners' report of this year contains a full account of the negotiations which led to the abandonment by the Power Company of their monopoly. The Commissioners say, that:

“As public sentiment appeared to favor the cancellation of the monopoly clauses in the Canadian Niagara Power Company's agreement, and the granting of equal rights to other Companies desirous of using the water power of the Falls for commercial purposes, the Legislature at its last session passed an Act conferring upon the Commissioners authority to negotiate with the Canadian Niagara Power Company for the surrender and abandonment of the sole and exclusive right to use the waters of the Niagara River within the limits of the Park, granted by the agreement of April, 1892, upon such terms and conditions as might appear to be necessary in the public interest.”

A new agreement with the Canadian Niagara Power Co. was negotiated and entered into without delay, and during the same year another agreement was entered into between the Commissioners and the Ontario Power Company, which was the second company to secure concession for utilizing the waters of Niagara on the Canadian side for the development of electrical power.

No doubt the Commissioners congratulated themselves upon the fact that these new agreements largely augmented their income; but I doubt if at that time they were optimistic enough to believe that within three years yet another company would apply for a franchise.

Up to 1902 all of the privileges on the Canadian side were being operated by United States capital, and Canadians had no part in the development of their magnificent birthright.

The Niagara Falls Park and River Railway had been promoted, constructed, and, for a short time, operated by a Canadian company, which finally sold out to the International Railway Company. The Canadian Niagara Power Company and the Ontario Power Company are both controlled by United States capital, and much credit is due to them for their foresight and

enterprise in being the first to take advantage of this opportunity for the investment of capital.

In 1902, however, Mr. Wm. Mackenzie, Col. H. M. Pellatt, and myself, made application for a site in the Park for the development of power on a large scale. Before this time the ability to transmit electrical energy for long distances at high voltages had not been commercially demonstrated, but as soon as it was known to be both feasible and successful, the question of generating power at Niagara Falls for transmission to Toronto became a live topic.

After protracted negotiations between the syndicate, the Ontario Government, and the Park Commissioners, a franchise was finally granted and an agreement entered into on the 29th day of January, 1903, and on the 18th day of February following, the Electrical Development Company of Ontario, Limited, was incorporated for the purpose of proceeding immediately with the development of their concession.

The capital of this company has been exclusively subscribed and paid for by Canadians, so that I am glad to be able to say that a more or less international reproach has been removed, and a Canadian company will be in a position

to engage in keen but, I hope, friendly rivalry with our enterprising neighbours who have spied out our land and shown their belief in its future by their deeds.

Having endeavoured to set forth chronologically the various undertakings and agreements precedent to the construction of their works by the three large power companies on the Canadian side, I will, before proceeding with the description thereof, refer as quickly as possible to their relation to the present and prospective flow of the river; because many people fear that when the power houses are in operation the flow of water will be so diminished as to appreciably interfere with the scenic beauties of the great cataract.

I have previously mentioned that the total estimated horse power of the river passing over the Falls is from six to seven million, and a later authority, Mr. James Wilson, Park Superintendent, estimates that, after making liberal deductions, a total of 5,500,000 H.P. electrically can be safely assumed, 90 per cent. of which is at the Canadian or Horse Shoe Fall.

When all the companies who are operating both on the Canadian and United States sides of the river have developed their concessions

to their maximum output, which of course cannot be for some time to come, only about 78,000 cubic feet out of 223,000 cubic feet per second will be diverted, leaving 144,000 cubic feet plus 25,000 cubic feet (which is taken from the United States side), or a total of 169,000 cubic feet remaining on the Canadian side to perpetuate the scenic effects of the Horse Shoe cataract.

Whether this deduction in years to come, of about 23 per cent. of the water passing over the brink of the Falls will detract from their grandeur, can only be estimated, but as a mere spectacle I am inclined to think that a depth of water of say from 12 to 14 feet projecting into the abyss below will be as awe-inspiring as ever.

It frequently happens that a strong wind blowing from the north holds back the water in Lake Erie, thereby reducing the head of water at the Falls by not less than two feet, and yet none but close observers can distinguish the difference. In fact, the cogent argument has been advanced by Dr. Martin, that a reduction of the quantity of water will actually help to conserve the scene as it exists to-day, for the terrific weight and rush of waters over the Horse Shoe Fall is eating it away and breaking its cliff into

a series of receding slopes and rapids, so that even a slight diminution of the whelming mass of wave will to that extent lessen its disruption and decay.

If, as all hope, and most of us believe, we can, without diminishing the scenic effects, turn to good use this mighty power, which Edison has termed "the greatest storage battery on earth," and which for countless ages has simply been running to waste, so far as its economical use is concerned, surely something will have been accomplished for the good of mankind.

In every part of Ontario to-day coal is being used in the mills, the factories, and the homes. This coal, which has been mined in a foreign country, is toil-won from the bowels of the earth, and after passing through many grimy processes is laden on cars or vessels before finally reaching its destination.

If we can secure our power and heat in a more acceptable form, without the grime and noxious fumes incidental to the use of coal, I say that something has been accomplished for the general good, and it is now my privilege to point out, not only how this is being done on a large scale, but how this more acceptable, but invisible and mystic power, which men call

electricity, will be transmitted along slender copper wires to great distances, and having silently entered our mills, factories and power houses, over still more slender wires, will, like the genii out of the bottle, expand into a force that is terrifying when uncontrolled.

It is the vocation of the modern engineer, however, to devise methods and machinery whereby this mighty force is absolutely under human control, led hither and whither at will, and divided and sub-divided as circumstances dictate. It is used for the propelling of mighty locomotives that can draw heavier trains, at a greater speed, than any steam locomotive ever built. It can drive the heaviest machinery in mill or factory, or from the same wires can propel the tiniest electric fan. It can, when used through the medium of the searchlight, project illumination through miles of space, and thus defend the fortress or the battle-ship from attack or disaster, and when held in bondage by a storage battery, may be used, as the reserves of a great army are used, only in times of stress or of critical emergency.

It is used as an implement of the wrath of man, when in the interests of justice the murderer atones for his crime in the electric chair of

death, and again, and in sharp contrast, man, when in nobler mood, uses its subtle healing and health-giving properties to alleviate pain and prolong life.

I have said this much in defence of those of us who, while as anxious as any to see the beauties of nature undefiled, believe that much good can be accomplished by utilizing Niagara's power, without doing violence to the aesthetic tastes of the antiquarian, the artist, or even a Cook's tourist.

The Park Commissioners, in their own wisdom, but at the expense of the Power Companies, have been rigidly insistent upon the various works of construction being so planned that when completed they will not only not detract from the physical beauty of their surroundings, but add thereto those monuments of engineering skill and modern achievement which I am about to describe, and which have been made possible only by the optimism of capital; and it is cause for congratulation that most of the possibilities of power development at Niagara are on the Canadian side, for although two of the three companies are controlled by United States capital, each of the agreements contains a clause

providing that not less than 50 per cent. of the power they may develop shall be held for use in Canada in the event of a demand arising therefor.

I estimate that the completed cost of the three great works now under construction will be from fifteen to twenty million dollars; and as the major portion of this vast sum is being expended in Canada for labor, materials, and machinery, and as at least one-half of the total output accruing from this expenditure is conserved for Canadian use, I submit that the Government and the Commissioners, while encouraging investment, have made excellent bargains with the Power Companies.

The first to commence construction was the Canadian Niagara Power Company, they being quickly followed by the Ontario Power Company, and later by the Electrical Development Company: and I will refer to the special features of each plant in this order.

CANADIAN NIAGARA POWER COMPANY.

The cofferdam of this Company consists of an inner and an outer cribwork, with a puddle space between; the outer cribwork is ten feet wide, the inner eight feet, and the puddle space

eight feet. The average depth of water is about sixteen feet.

After the cofferdam was constructed, so much water leaked through the boulders between the puddle and solid rock that it was found unreasonably expensive to do the necessary pumping, so the inside of the cofferdam was covered with two layers of tongued and grooved sheathing breaking-joints, and between which was placed a layer of tarred paper, all well spiked to the timbers.

The works being constructed are designed for a capacity of 110,000 horse-power. The general design is similar to that of Power House No. 2 of the Niagara Falls Power Company now in operation on United States side of the river.

The tunnel tailrace, which leads the water to the lower river after it has left the turbines, is 2,200 feet long and of a horse-shoe form, 25 feet high and 19 feet wide, being lined with 17 inches of concrete with vitrified brick facing, except for 100 feet at river end where the tunnel drops by an ogee curve into the river.

The grade of this tunnel is seven feet per thousand, which will give a speed of water, when the plant is in full operation, of 27 feet per second.

The rock through which the tunnel was excavated is limestone and black shale. The former provided a good roof, but where shale was encountered timber arches resting on wall plates and plumb posts were put in to retain roof. The excavation of the tunnel was completed before the permanent lining was begun.

The head canal, built entirely of massive limestone masonry, has a clear waterway 15 feet deep and 250 feet wide, and is crossed by a five-span stone arch bridge which carries the tracks of the Niagara Falls Park and River Railway, a carriage way, and a sidewalk. The canal widens into a forebay 600 feet wide, extending the whole length of the Power House.

Protection from ice is afforded by an outer ice rack along river face ; a line of submerged arches forming outer wall of forebay room ; a fine ice rack extending the whole length of Power House inside the forebay room and immediately outside the penstock mouthpieces, and by an overflow weir which can be used in combination with floating booms to draw floating materials back into river again by means of a sluiceway channel.

The wheelpit is 165 feet deep, 18 feet wide inside of brick lining, and 570 feet long. The sides were channelled in six-foot cuts.

Five chambers for auxiliary machinery were excavated in east side of wheelpit as the work progressed.

The wheelpit is lined with hard burned brick. The course next the rock is composed of hollow brick, and ample weepers emptying into the tail water are provided.

The turbines, each of a capacity of 12,500 horse-power, were designed by Messrs. Escher, Wyss & Company, of Zurich, Switzerland, and are of the twin Francis vertical type, inward discharge, two draft tubes to each unit discharging into the open tailrace below. Three of these units were manufactured and are being installed by this firm, and two units on the same design are about to be installed by I. P. Morris Company, Philadelphia, Pa.

One of the most distinctive features of this plant is the size of the generating units, each of which is to have a capacity of 10,000 horse-power. The plant when completed will contain eleven of these generators.

The generators with vertical shafts are of internal revolving field type, and are wound for three-phase current, 11,000 volts, 25 cycles at 250 revolutions per minute. This high generating voltage was selected not for long distance

transmission, but for economy in local distribution of power.

The cost of distributing at 11,000 volts, three-phase, is about one-fifth that required for a 2,200 volt, two-phase system. For long distance transmission step-up transformers will be used to raise the voltage to 22,000, 40,000 or 60,000 volts, depending upon the distance of transmission.

It is the intention to have cable connections so that this power house can operate, if desired, in parallel with either or both of the United States plants of the Niagara Falls Power Company. The cables will be carried across the Niagara River by way of the Upper Steel Arch Bridge, a total distance of about three and one-half miles. The 11,000 volts, three-phase, will be changed to 2,200 volts two-phase, for paralleling, by means of step-down transformers, or delivered direct to tenants on the lands of the Niagara Falls Power Company.

The auxiliary machinery, consisting of exciter turbines, exciters, water pumps, oil pumps, oil tanks, etc., are located in the chambers built into the side of the wheelpit, 100 feet beneath the surface. This machinery will all be operated by an independent water service drawn from the canal above.

The present Power House building, for five units, is constructed of Queenston limestone, roofed with tile, and has installed two 50-ton electric cranes for service in installation of machinery. It is lined inside with mottled buff brick, enamel brick and marble.

Underground conduits from Power House to Upper Arch Bridge have a capacity of 75,000 horse-power, and from Power House to a Transformer Station situated south and outside of Queen Victoria Park a capacity of 50,000 horse-power.

A Transformer House, equipped with water-cooled transformers, has been constructed of a present capacity of 25,000 horse-power. It will be supplied with water for cooling purposes from pumps located in chambers of wheelpit. There is also a standpipe, 116 feet high by 30 feet in diameter, carrying one day's supply of water, to be drawn upon in case of any accident to this pumping system.

Every effort has been made in the construction of these works to build for the future. Stone, brick and cast-iron have been chiefly relied on, and, where used, steel work has been designed so as to be accessible for inspection, removal and painting. The Power House and

Transformer Station are practically fire-proof, the roof tiles being laid directly on the steel roof angles.

In the design, all the experience gained in the construction and operation of the plants of the Niagara Falls Power Company has been made use of, and it is believed that the works herein described represent the best hydraulic, mechanical and electrical knowledge available to date.

THE ONTARIO POWER COMPANY.

The plan of development followed by this Company is essentially different from either of the two other Companies. Instead of taking the water from the river at the Power House, conducting it through penstocks to the turbines in the wheel-pit below and discharging it into the lower river by means of a tunnel, they gather the water required at their head works at the upper end of the Park, conduct it through a steel pipe of over 6,000 feet in length to a point in the cliff below the Falls, thence by penstocks in tunnels through the cliff to the Power House in the Gorge. I understand it is the intention of the Company to ultimately utilize three of these steel pipes, each having a capacity of

60,000 horse-power, but at the present time one only has been constructed. The general details of this plant are outlined in the following description :

The headworks consist of an intake proper, and outer forebay, screens, an inner forebay and control gates.

The intake, 618 feet long, consists of concrete piers, supporting a continuous, reinforced, concrete curtain wall. More than double the quantity of water to be utilized at the water wheels is intercepted by the up-stream face of the intake, and much is there deflected to form a cross current which will carry away ice. This is brought about by a curtain wall construction and the placing of the structure at an obtuse angle to the natural direction of the current in the river.

The outer forebay, which contains an area of eight acres, is bounded by an artificial island and the original river bank on the one side, and by a long concrete gathering wall on the other. A supply of water is provided for the restoration of the Dufferin Island Channel, which is controlled by sluices on either side of the island mentioned.

Except during extremely low stages of water in the river, the outer wall of the forebay

will be constantly submerged, water spilling freely over it into the river, as over a weir, carrying floating ice and debris with it. A section of this wall, 100 feet in length, adjacent to the screen house, is constructed with the top depressed below the crest of the main portion. When water at the intake is at extreme low level, there is thus an additional discharge area of approximately 300 square feet cross section over the depressed section.

The screens are in the form of a steel grillage, set on inclined guides in concrete masonry, and are removable by means of a crane. The apparatus is covered by an artistic stone building, the roof of which forms a broad promenade, commanding an exceptionally fine view of the rapids.

The inner forebay, with an area of two acres, extends from the screen house to the gate house. The landward wall and the river wall are formed partly by the rock face after excavation had been made in the river bed, and partly of concrete. On the land side, excavated material has been dumped and graded to bring the general surface of the islands in this vicinity up to the same level as the top of the concrete wall, at elevation 560. The original Dufferin Islands

have been increased in area, and several entirely new islands of considerable size have been made from the excavated rock, approximately 150,000 cubic yards, taken from the bed of the river in deepening the two forebays..

The quantity of water that will be drawn into the inner forebay when the entire capacity of the plant is being generated has been calculated to be in the neighborhood of 12,000 cubic feet per second. The depth of water in the headworks under normal conditions of river gradually increases from 13 feet at the intake to 30 feet at the gate house. The velocity of flow is about three feet per second at the intake ; it is swiftest (4.7 feet per second) through the centre portion of the outer forebay, and it drops to two feet at the screens, then gradually increases to 3.4 feet per second at the gate house.

The gates at the entrance to the conduits are three in number, one for each of the main conduits. They are of the Stoney pattern, of square form, full size of their respective conduit, and counterbalanced to run between roller guides. A substantial and artistic building covers the gates, and an equipment of boilers and steam pipes provides against freezing.

Starting from the gate house, the main conduits, three in number, follow the river bank through the Park to the top of the cliff opposite Goat Island. The distance to the nearest penstock is 6,180 feet, in which length the fall in grade is 28 feet. The first of the three conduits which is now nearing completion, is 18 feet in interior diameter. When flowing at full capacity it will pass about 3,900 cubic feet of water per second.

From the underside of the first main conduit, six penstocks, each nine feet in diameter, drop in pairs through vertical shafts and out through horizontal tunnels in the solid rock of the cliff to the Power House. Each penstock supplies water for a 10,000 horse-power unit.

The building is 76 feet wide and 65 feet high, and for the full capacity will be about 1,000 feet in length. The roof is flat, and the general style of architecture is massive and somewhat after the Egyptian order.

The main generators and their turbines, directly connected, are the only machines placed on the floor of the station.

On a raised gallery, 11 feet above the main floor, and extending along the rear wall of the station, are located the exciter turbines, the

direct connected exciting dynamos, and the governors that regulate the speed of the turbines.

At a distance of 550 feet back from the generating station, and on the bluff, at an elevation of 250 feet above it, is situated the control, transforming and distributing station. This distant control removes from the generating station the possible dangers incident to the operation of high voltage switches for generators, as well as for transformers, and also concentrates the management of both in a single operating room.

The distributing station building is of imposing appearance, as it occupies a prominent position on the bluff overlooking the Park and Horse Shoe Falls. A wing to accommodate the offices of the Company extends forward in the centre.

THE ELECTRICAL DEVELOPMENT COMPANY OF ONTARIO, LIMITED.

The foregoing particulars regarding the operations of the Canadian Niagara Power Company and the Ontario Power Company respectively have been taken from various reports published from time to time, with their authority, but in view of my personal identification with the operations of the Electrical

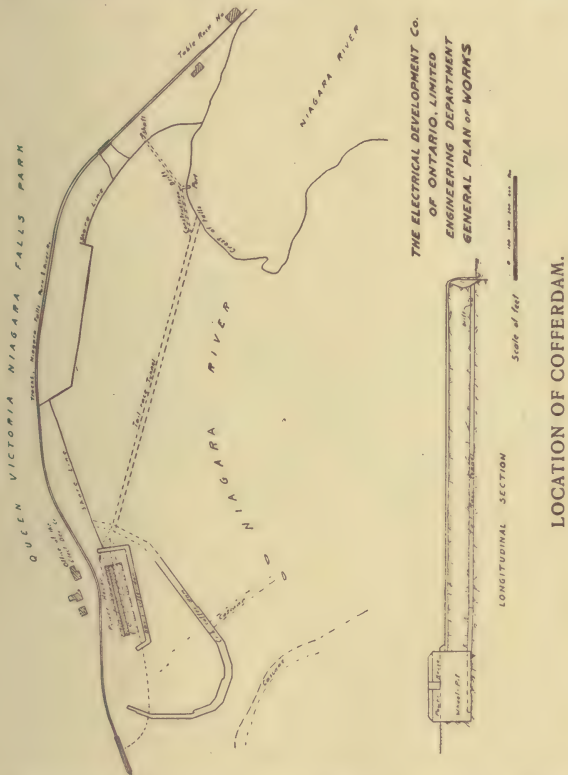
Development Company, I am able to describe this enterprise with somewhat greater elaboration of the special engineering features in connection therewith.

On January 29th, 1903, an agreement was entered into between the Commissioners and Messrs. Wm. Mackenzie, H. M. Pellatt and Frederic Nicholls, granting rights to take water from the Niagara River at Tempest Point, for the purpose of generating electricity to the extent of 125,000 electrical horse-power.

On the 18th February, 1903, The Electrical Development Company of Ontario, Limited, was incorporated by Letters Patent under the authority of the Legislature of Ontario, with a Capital Stock of \$6,000,000.00.

At a meeting of the shareholders held on the 21st March, 1903, the agreement made between Messrs. Mackenzie, Pellatt and Nicholls and the commissioners, was acquired by the Company, and the following Directors were elected: Messrs. Wm. Mackenzie, Col. H. M. Pellatt, Frederic Nicholls, Hon. Geo. A. Cox and James Ross. Subsequently Col. Pellatt was elected President, Frederic Nicholls, Vice-President and General Manager, and Wm. Mackenzie, 2nd Vice-President. At the same meeting

H. G. Nicholls was appointed Secretary, and Mr. D. H. McDougall Treasurer; Mr. F. S. Pearson, Dr. Sc., was appointed Chief Consulting Engineer, Mr. Hugh L. Cooper, Chief



Hydraulic Engineer, Mr. Beverly Value, Chief Engineer of Construction at the Works, and Mr. H. H. Macrae, Solicitor.

Since that date no time has been lost in expediting operations in order that the enterprise may become income-producing at the earliest possible period.

The first and most important part of the work was the final location of the site by the Company's Chief Hydraulic Engineer, and the preparation of the necessary plans to enable construction to be proceeded with, and it is but just to say that never was engineering skill of a higher order shewn, as the practical completion of the hydraulic construction has proved the preliminary studies to have been both correct and admirably designed.

Our development radically differs in many ways from any of the others on either side of the river. A novel feature is that all the works of the Company are practically constructed on what was previously the river bed—that is to say, that no encroachment has been made on Park territory, but the room required has been wrested from the most turbulent part of the upper rapids at Tempest Point. To accomplish this it was a necessary preliminary to construction to unwater about twelve acres of the river, and the doing of this called for much engineering skill. The contractor having failed,

however, to make the dam watertight, our engineering staff subsequently executed an inner dam which secured the desired result.

With the forebay unwatered, work was begun on the headworks. A concrete gathering dam, with granite coping, extending up stream from the lower end of the wheel-pit



COFFERDAM DURING CONSTRUCTION

at an angle of thirty degrees, conducts the water to the gates, increasing the available head and stilling the water. This dam is designed to act as a spill-way for its entire length, thus enabling the surface ice to escape before reaching the submerged arches



EXCAVATION FOR WHEEL PIT.

mentioned later. This action is still further increased by having the top of the last sixty feet—at the down stream end—three feet lower than the rest of the dam. The heavy ice will be that brought down from the upper lakes in the early spring. It is not expected to be large in amount, as most of it passes down the river near the centre of its flow. However, ample provision is being made to handle whatever amount may possibly come. The water before reaching the penstocks will have to pass through two rows of submerged masonry arches, separated by a quiet bay equipped with a spill-way at its lower end for passing off such ice as may be in it. Between the second row of arches and the gates, lies a second bay equipped with a small spill-way at the end, and with a set of metal gratings in front of each gate. This last bay comes beneath the limits of the power house or generating station, and will consequently be covered.

Nor was the work preliminary to the excavation of the main tail-race tunnel less devoid of excitement and risk, which at one time amounted to heroism. The main tunnel, which is the largest tunnel in the world, is about 2,000 feet in length by about 33 feet in diameter in



PERMANENT CONCRETE DAM.

the rough, that is to say, before it is lined with cement, concrete and hard burned brick, which will reduce its area to 26 by 23½ feet. It is constructed 158 feet below the bed of the river, commencing at the end of the wheelpit, and discharging behind the falling waters of the Horse Shoe Fall about 700 feet from the shore. In order to reach this outlet, a shaft was sunk at the brink of the Falls to a depth of 150 feet, and a construction tunnel 14 by 7 feet was driven to the point 700 feet distant, where excavation of the main tunnel would be commenced. When about half of the distance had been driven it was decided by Contractor Douglass to excavate an opening for the construction tunnel to the chamber between the face of the cliff and the falling water, for the purpose of dumping the debris into the river and save hoisting it up the shaft.

The first hole was made near the ceiling of the drift, and immediately dense clouds of spray rushed in through the opening, and water, intercepted by the talus, began to rise in the floor of the tunnel. Powerful pumps were set to work to keep the water down, but the task was beyond them, and the water steadily rose until only a small space remained between it and the roof.

If the rock at the mouth of the opening—which acted as a dam—could be removed, the water would immediately run out, but how to remove it was a puzzle. The emergency developed volunteers, and three were selected for a most dangerous service. A flat-bottomed boat was lowered down the shaft to the end of the flooded tunnel. It rode so high that it would not clear the roof, and ballast was put in to make it ride lower. The three men, with several boxes of dynamite and a lot of copper wire, then started on their voyage by lying down on their backs and propelling the boat by pushing with hands and feet against the ragged roof. When they reached the opening several hundred feet away, they placed the dynamite, connected the wires, and started on the return journey, the boat sinking under them just as they reached the shaft. The dynamite was exploded, but failed to entirely remove the obstruction, when another and equally daring method was tried.

Our Chief Construction Engineer and two men, roped together like Alpine guides, started for the opening along the face of the cliff behind the Falls. At all times the spray was blinding in its intensity, and gusts of wind or compressed air would almost beat them to the ground, but



MAIN TAIL RACE TUNNEL.

they persevered until success crowned their efforts, and they stood in front of the opening, having ventured such a distance behind the Falls as had never previously been accomplished.

Here the difficulty was diagnosed, and subsequent trips were taken to place a huge quantity of dynamite where it would do the most good, and on one Saturday at near midnight the charge was electrically exploded. Supreme effort met its just reward. I am glad to say the obstruction was removed, and the water ran out of the tunnel, and ever since then there has been no setback of any kind, and the enormous tunnel, which has now been driven its entire length, is as dry and pleasant as this room.

Apart from its being the largest tunnel ever constructed, there are several novel engineering features connected with it. Instead of commencing directly under the wheelpit, it starts with two branches, one on either side of the wheelpit. These join at a point 165 feet beyond the end of the wheelpit, forming a section 26 feet high and $23\frac{1}{2}$ feet wide, of a horse-shoe form, the object of the water wheels discharging alternately into a branch tunnel on either side instead of into one main tunnel beneath, being to enable one half of the Power House to be

shut down at any time for examination or repairs, a feature unique with this installation. It is estimated that with the complete plant in operation the velocity of the discharged water will be 26 feet per second, and the quantity about 12,000 feet per second.

Over the wheelpit will be the Generating Station or Power House. Its style of architecture on the outside will be Italian Renaissance, and its classical lines are a tribute to the skill of the Architect, Mr. E. J. Lennox. As previously mentioned, it is on the bank of the river at a somewhat higher elevation than the main Park drive-way, and to overcome the difference in elevation, broad terraces, enhanced here and there with parapets and wide flights of steps, will be constructed, adding materially to the æsthetic appearance of the landscape at this point. A wide colonnade, supported by massive stone columns, graces the entire front of the structure, and from this colonnade visitors will be able to view, through large plate glass windows, the complete operation of the massive machinery within the building.

For the purpose of providing manufacturing sites for industries which may desire to locate near Niagara Falls in order to use the power of



ELECTRICAL DEVELOPMENT COMPANY'S POWER HOUSE.

this Company, some 530 acres of land have been purchased fronting on the Chippewa River, about two miles from Niagara Falls and only three and a half miles from the point where the Chippewa River has entrance to the Welland Canal. These lands have a river frontage of one and one half miles and will have excellent water and railroad communication.

The power generated will be delivered by underground cables to the step-up terminal station of the Toronto & Niagara Power Company, which has been organized to distribute the output of the Electrical Development Company's Power House. This terminal station is located on the top of the Niagara Embankment above the Park, about 1,500 feet from the Power House. It will be about 200 feet long by 65 feet wide. The current will be delivered at about 12,000 volts, where it will be raised by the step-up transformers to 60,000 volts for transmission to a similar transformer station building at Toronto, where it will be reduced by step-down transformers to the commercial voltage required. Although the first transmission line is being built to reach Toronto, the Company having secured contracts for a large block of power from the Toronto Electric

Light Co. and the Toronto Railway Co., it is intended to later on construct transmission lines to such other points in Ontario, within a



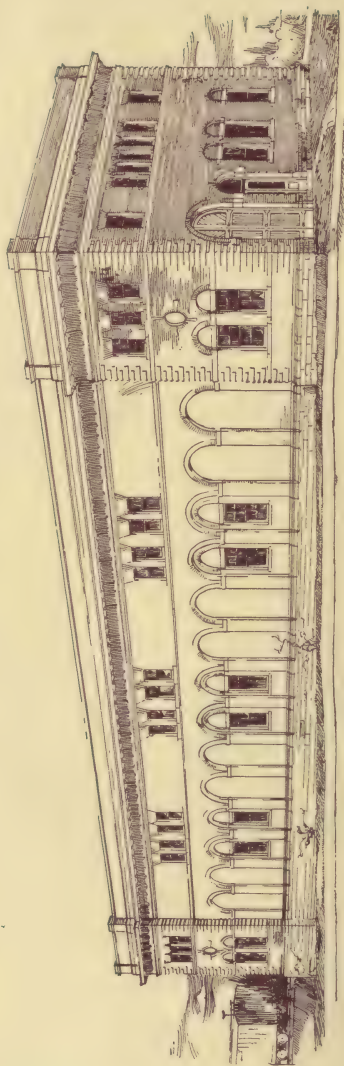
TRANSMISSION TOWER.

distance of say 150 miles from the Generating Station, where a market can be found that will warrant the cost of constructing transmission

lines. The Niagara-Toronto line is being built within a private right of way, and steel towers are used instead of wooden poles for supporting the copper cables. Mr. W. T. Jennings, M.I.C.E., was appointed Chief Engineer in charge of the locating survey, which has been conducted with ability by himself and his staff of assisting engineers. The route having been located, the purchase of the right of way from hundreds of owners was commenced, and through the untiring efforts of the Company's Solicitor, Mr. Macrae, and his assistants, this difficult task has been satisfactorily completed.

This ends a very brief description of the several works in course of construction, but before concluding I will, even more briefly, refer to the strides that have been made in electrical science during the last few years.

Seventeen years ago a convention of street railway men, meeting in the United States, refused to listen to one of its members who advocated the merits of electric traction, and instead devoted their time to questions connected with the feeding and stabling of horses and mules. To-day there is scarcely a horse-car remaining in service on this continent.



TERMINAL SUB-STATION.

During the earlier years of electric traction, when horse-car companies were being rapidly converted by the logic of events, the trolley cars of the period were about the same size as the horse-cars they replaced, and had as motive power one or two 15 H.P. motors. To-day in urban service, large cars, using powerful motors are in daily use, and for inter-urban service cars weighing 48 tons with a 600 H.P. equipment are in use between many cities in the United States. Although we have not yet progressed to that extent in Canada, at least one project is under way for instituting an electric trunk line service that will be modern in every respect. As the horse-car men of old (I say of old, for seventeen years retrospect in electrical matters is ancient history) belittled the possibilities of electric traction on the streets and highways, so until a very recent period have the steam railway magnates looked askance at the question of operating their lines by electric power. But history is being made rapidly, and a new epoch was begun when the New York Central R. R. placed an order for fifty electric locomotives, capable of handling the heaviest trains for use between New York and cities within a radius of 24

miles, in order to abolish the disadvantages of steam traction within New York city and suburbs. The first of these locomotives has been built and tested, and in the trials proved superior in speed and tractive force to the best New York Central locomotive.

To drive these locomotives an immense steam power house is being erected, and with vast quantities of power developed at Niagara



MODERN ELECTRIC LOCOMOTIVE.

one cannot be accused of undue optimism when anticipating great future developments of electric traction adapted to steam railroads.

I could descant at much greater length upon all the varied improvements that have recently taken place, and the prospects for future applications of electric current in electro-chemical industries and various branches of arts and

science, but such would be sufficient to form the topic for a paper by themselves, and I have already trespassed on your indulgence, and will at once conclude.

To "harness Niagara," which had been long a dream, is now an actuality, as I have shown. The possibilities of future invention and discovery in the field of electric science are limited only by the imagination. A single generation has seen the commercial development of electric light, electric railways, the telephone, the phonograph, and wireless telegraphy, any one of which, if even hinted at in what we are pleased to call the "good old days," would have been sufficient grounds for burning at the stake for witchcraft.

In face of such modern miracles can we conclude that we have reached the limit of advancement? I think not, and venture to prophesy that in the future will be celebrated greater marvels than in the past, and if it should fall to the lot of any of us to be present at such a celebration I can express no better wish than that we may at that time be surrounded by such a goodly company as are gathered here to-day.

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